Instruction Bulletin

Decade Isolation Amplifier
Model 102A

KEITHLEY INSTRUMENTS

CLEVELAND, OHIO

INSTRUCTION BOOK

DECADE ISOLATION AMPLIFIER

MODEL 102A
MODEL 102A-R1
MODEL 102A-R2

MODEL 102A-P1 PROBE
MODEL 102A-P2 PROBE

KEITHLEY INSTRUMENTS

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Cleveland 15, Ohio

SECTION I GENERAL, 102A

The Keithley Model 102A Decade Isolation Amplifier is a general-purpose laboratory instrument. With its high input impedance, low output impedance, and wide range of accurate gains, it can be used in most applications requiring amplification in observation and test equipment or as part of an operating system.

The Model 102A can be used to amplify the output of pressure pickups, accelerometers and other low-level or high impedance transducers for examination by various oscilloscopes or analyzers. It is also used for bridging test and analysis equipment, such as vacuum tube voltmeters and oscilloscopes, onto high impedance vacuum tube circuits. The choice of connecting directly to the input terminals of the Model 102A through the Models 102A-P1 and 102A-P2 Probes, or through special connectors assembled by the user, provides further flexibility.

Cathode ray oscilloscopes, analysis and recording apparatus, and a majority of electronic voltmeters have input impedances of about 0.5 to 2 megohms shunted by 15 to 40 mmf. Test leads add from 10 to 60 mmf more capacitance. The characteristics of a high impedance circuit, such as a pentode amplifier stage with a one-megohm plate load resistance or a crystal transducer are appreciably changed when such instruments are connected directly to it. The Model 102A with its input impedance of greater than 250 megohms shunted by 3 mmf, however, can be connected to a typical high impedance circuit or transducdr without affecting its operation. The output impedance of the 102A is sufficiently low that test instruments will operate from it without error.

Moreover, whenever it is desired, several instruments can be connected to the output of the 102A. If both a voltmeter and an oscilloscope are used, a continuous check is available that the voltage is the one desired; any undesirable distortion or pickup of spurious voltages is immediately apparent. Or, if the wave form is of primary interest, the voltmeter gives a continuous indication of the signal level. Aural monitoring can also be incorporated as an additional check on the voltage or to give the tone of a wave form. Or, again, if the tone is of paramount interest, the signal level and wave form are continuously available.

In addition to the convenience of having the magnitude of the signal, the wave form, and the tone simultaneously available, much time is saved in not having to clip or switch the test signal leads among the measuring instruments. Even if the circuit has a low enough impedance to drive all the test instruments together, the 102A simplifies the connections, for only one test lead has to be moved about the circuit, not several from several instruments.

SECTION I GENERAL, 105A

SECTION II DESCRIPTION, 102A

The Model 102A Decade Isolation Amplifier consists of four major electrical sections as shown on DR 10714-C, enclosed: the input, V1 and V2; middle amplifier, V3 and V4; output amplifier, V5 and V6; and the power supply, V7, V8, V9, and V10.

Because of the feedback from V2, V1 has a very high effective input resistance and a low input capacitance. Enclosing the input coupling capacitor in a driven shield reduces the stray input capacitances to a total of 3 mmf. The driven shield is also connected to the pin jack between the input terminals for driving shielding in a Model 102A-P1 Probe.

The driven shielding potential is just slightly less than the instantaneous potential of the signal conductor. The circuit or transducer being tested, therefore, has to supply only a fraction of the usual charging current, thus reducing the effective input capacitance of both the internal wiring and an external cable with the driven shield. In other words, V2 of the input amplifier supplies the charging current for the input.

On gains of x1000 and x100, both the middle and output amplifiers are used; a 10:1 attenuator is used just ahead of the output amplifier on gain of x100. On the lower gains, the middle amplifier is disconnected from the circuit and the output amplifier and the attenuator between it and the input control the overall gain of the instrument.

The input section has a gain of essentially 1.00, the middle amplifier 100, and the output amplifier 10.

Accurate and stable resistors, substantial feedback, and the regulated power supply assure accuracy of the gains.

The 102A is housed in an upright cabinet, with the control panel on the front. The GAIN is the most prominent control, located in the middle. The power switch and pilot light are in the upper left corner. The input terminals are in the lower left corner, and two sets of output terminals in parallel are at the lower right.

The power cord is at the rear of the cabinet, and connects directly to the 50-60 cps power source.

The Models 102A-R1 and R2, comprise 1, or 2 units mounted on a $5\frac{1}{4}$ x 19 inch relay rack panel. The controls are the same as on the 102A.

Maximum and Minimum Input Voltages The Maximum voltage permissable at the input is 40 rms with a sinusoidal wave, or about 110 volts peak-to-peak.

This is with the gain set at 0.1 and at frequencies below 20 kc. Above 20 kc, the input stage is no longer linear at such high levels, and cannot handle such a large signal.

With gains of 1.00 through 1000, the maximum input signal is that which is consistent with producing a maximum output of 5 volts rms.

The input coupling capacitor has a rated breakdown of 1600 volts. We recommend, however, that measurements be limited so that no more than about 750 volts dc is ever applied to the 102A input.

The noise background of the Model 102A is equivalent to less than 35 microvolts at the input with the test leads connected together. Signals as low as 0.15 millivolt can be measured and observed with reasonable accuracy, but voltmeter errors increase rapidly as the level becomes lower, and cathode ray oscilloscope patterns become confused when the test signal level is not very much greater than the background.

As the impedance of a signal source is increased, the effective noise background of a connected amplifier increases. This is caused by increased thermal noise in the source and the characteristic operation of the input tube. The grid of the input tube also picks up filament and plate ripple voltages when it is not connected to ground through a low impedance.

The noise level of an amplifier is conventionally given with the input short circuited. Because the Model 102A is intended to work with high impedance signal sources as well as low impedance ones, the following table is included.

TABLE I, TYPICAL NOISE EQUIVALENT AT INPUT

Gain	Input Shorted	1 meg 500 mmf	1 meg 22 mmf	20 meg 22 mmf	102AP1* Probe	102AP2* Probe
0.1	5 mv	5 mv	5 mv	16 mv	4 mv	4 mv
1.0	0.5 mv	0.5 mv	0.5 mv	1.6 mv	0.4 mv	0.4 mv
10.0	80 uv	80 uv	90 uv	1.6 mv	90 uv	70 uv
100	30 uv	50 uv	60 uv	1.6 mv	90 uv	55 uv
1000	30 uv	50 uv	60 uv	1.6 mv	90 uv	55 uv

* Note: Probes measured with 1 meg across input.

When using the Model 102A in conjenction with other instruments, the gain of the 102A should always be as high as possible without overloading, and the gain of the equipment following it should thus be as low as possible so that the noise in the late stages of the Model 102A will be amplified the least. This gives the highest signal to noise ratio.

Thus, if a 10 millivolt signal is being measured, the 102A gain should be set at 100 to make the output one volt, and a voltmeter or scope set so that the one volt gives the proper reading or picture.

Gain and Frequency Response The Model 102A has gains of 0.1, 1, 10, 100, and 1000. At nominal line voltage, and at midband frequencies, these values are accurate to within a fraction of a percent. About a 1% change in gain can be expected as the line voltage is raised from 105 to 125 volts.

On all gains the response will be within 2% of midband from 3 cps to 300 kc. The high frequency response is within 3 db of midband gain to frequencies greater than 1 mc for all ranges. The low frequency response is within 3 db of mid-band gain to below 2 cps. on all ranges.

The regulated B supply aids materially in reducing spurious low frequency output caused by line voltage changes. These changes cause the pattern on an oscilloscope screen to shift when observing low level signals, if the oscilloscope amplifiers have response below about 1 cps. Normally, the 102A will be much more insensitive to line changes than the associated apparatus. The ultimate in stability will be obtained by using a line voltage regulator which keeps the 102A filament voltage constant as well as the plate voltage.

Maximum Output Voltage The maximum undistorted output voltage permissible up to 300 kc is 5 volts rms. Above 300 kc, the undistorted output decreases gradually to 1 volt rms at 1.5 mc.

When the Model 102A is lightly loaded and the signal frequency is low much larger undistorted output signals can be developed.

Output Impedance The dynamic internal impedance is less than 100 ohms resistance in series with 20 mfd. The impedance is constant for all GAIN settings.

5000 ohms is the lowest impedance which should be connected to the Model 102A output if the rated output voltage is to be developed, and the normal frequency range employed.

In general, the output impedance is low enough so that several instruments can be connected simultaneously to the output of the Model 102A without causing errors greater than a fraction of a percent.

SECTION III OPERATION, 102A

The Decade Isolation Amplifier is shipped ready to operate. Connect the power cord, and turn the On-Off switch to On. Normally, one minute is all the warmup period that is required; if the instrument has been idle for a long time, however, it should be allowed to run for about ten to fifteen minutes before it is used quantitatively.

In making measurements, a probe or leads are connected from the input terminals to the circuit whose characteristics are to be studied. The desired measuring and indicating instruments are connected to the Output terminals. The GAIN is then adjusted for best operation.

A certain amount of caution should be observed when using a sensitive voltmeter with the Model 102A. Because of the extremely high input impedance, pickup of stray fields is rather large, and as much as 30 volts can be developed at the output when the test leads are lying unconnected.

The input terminal arrangement permits a large variety of applications of the 102A:

a) Direct Connection: Circuits can be connected directly to the input terminals in conventional fashion.

b) 102A-P2 Probe: Low capacitance cable can be used for a connection to the 102A. The Keithley 102A-P2 Probe uses coaxial cable having 6 mmf per foot, and gives a direct connection from the signal source to the 102A. It has a total input capacitance of about 20 mmf. The advantage of this type of connection is the use of the 102A to above one megacycle. The disadvantage is a slightly high input capacitance.

c) 102A-P1 Probe: A driven-shield cable can be connected to the input terminal assembly. The Keighley 102A-P1 Probe uses a driven shield between the signal conductor and the outer grounded shield. The overall input capacitance is reduced to 5 mmf. The disadvantages are the limitation of the frequency response to 100 kc and a noise level of 50-90 microvolts rms with a one megohm source, a bit higher than with the 102A-P2.

d) Special Inputs: The user can construct special input circuits using the most suitable input receptacles and cables. One suggestion is the use of low capacitance cable with a divider in the probe to increase the input impedance further. Another suggestion is to use the shield terminal of the 102A input to drive a specially shielded configuration around a connector or a doubly shielded cable. In using the driving amplifier, two limitations should be kept

in mind. First, the amplifier is limited in its driving capabilities; Table II gives the relationship between the capacity of the driven shielding to ground and the maximem working frequency. The other limitation is that a driven shielded input has a negative input resistance at the higher frequencies. This is of no consequence with capacitive or resistive signal sources; but with inductive signal sources, oscillations are produced at the resonant frequency of the capacitance of the signal conductors to the driven shielding and the inductance of the source. A 100,000 ohm resistor in series with the HI conductor of the probe usually suffices to supress the oscillating condition, and does not greatly affect the frequency response of the system. Any specially constructed shielding should also use a similar resistor with inductive signal sources. The inductances are sometimes the residual inductance of a wire-wound resistor, or the effect of the mass of a crystal transducer, as well as components designed primarily to be inductors.

TABLE II

MAXIMUM UNDISTORTED SHIELD VOLTAGE

FREQ. cps	DRIVENSSHIELD CAPACITANCE		
	100 mmf.	300 mmf.	1000 mmf.
1000	40 rms volts	40	40
3000	40	40	40
10,000	40	40	35
30,000	40	38	20
100,000	30	13	3.5
200,000	15	3	1.5

NOTE: The capacitance of the driven shield to ground in the Keithley 102A-P1 Probe is about 100 mmf.

SECTION IV MAINTENANCE, 102A

The gains of the Model 102A should remain at their initial values indefinitely, because of the stability of the precision wire-wound resistors and large negative feedback. It is advisable, however, that the midband gains and high frequency response be checked occasionally with precision instruments to assure continuing accuracy.

To make any readjustments, it is necessary to remove the cabinet from the chassis and panel assembly. After the three screws on each side of the cabinet are removed, the cabinet can easily be slipped off. For safety, the power should be turned off during disassembly and re-assembly.

Table III, below, shows the working gains of the two amplifier circuits and the attenuation between them to obtain the various gains marked on the panel. Amplifier A is the V3-V4 circuit, and Amplifier B is V5 and V6.

TABLE III

GAINS OF VARIOUS SECTIONS OF MODEL 102A

GAIN Step	Input Stage	Amplifier A	Voltage Divider	Amplifier B	Overall Gain
0.1	1.0	-	1/100	10	0.1
1.0	1.0	-	1/10	10	1.0
10	1.0	-	1/1	10	10
100	1.0	100	1/10	10	100
1000	1.0	100	1/1	10	1000

Both amplifier A and amplifier B use large amounts of negative feedback to stabilize their gains, which should remain accurate as long as the components in the amplifier are working properly. If an error in the gain is detected, the tubes are most probably at fault. If the tubes appear satisfactory, however, their electrode potentials should be checked to ascertain that the plate and filament supplies and the amplifier components are in working order.

Troubles can be localized by noting that on Gain of 10, only the input and output (B) amplifiers are in the circuit, and on Gain of 1000 all three amplifiers are connected directly. Other steps use the voltage dividers as well as the amplifiers.

At the factory, the high frequency responses are trimmed in by the following steps:

1) Gain at 10, C313(output amplifier trimmer) is adjusted for zero gain error at 300kc.

2) Gain at 1000, C208 (middle amplifier trimmer) is adjusted for zero gain error at 300kc.

3) Gain at 100, C301 (divider padder) is adjusted for zero gain error at 300kc.

4) Gain at 1.0, C302 is adjusted for zero error at 300kc.

5) Gain at 0.1, C303 is adjusted for zero error at 300kc.

Note: there is interaction between the settings of steps 4 and 5, and the final setting is reached through successive approximations.

The two amplifier trimmers are located adjacent to their associated tubes, and are accessible from the back of the instrument, with the cabinet removed. The divider padders are mounted on the bracket holding the gain switch to the chassis, and are labelled 100, 1, and 0.1 for the gains which they adjust.

All readjustments, of course, should be carefully made with very accurate instruments.

The frequency response and gain of the input stage should not change unless something is radically wrong.

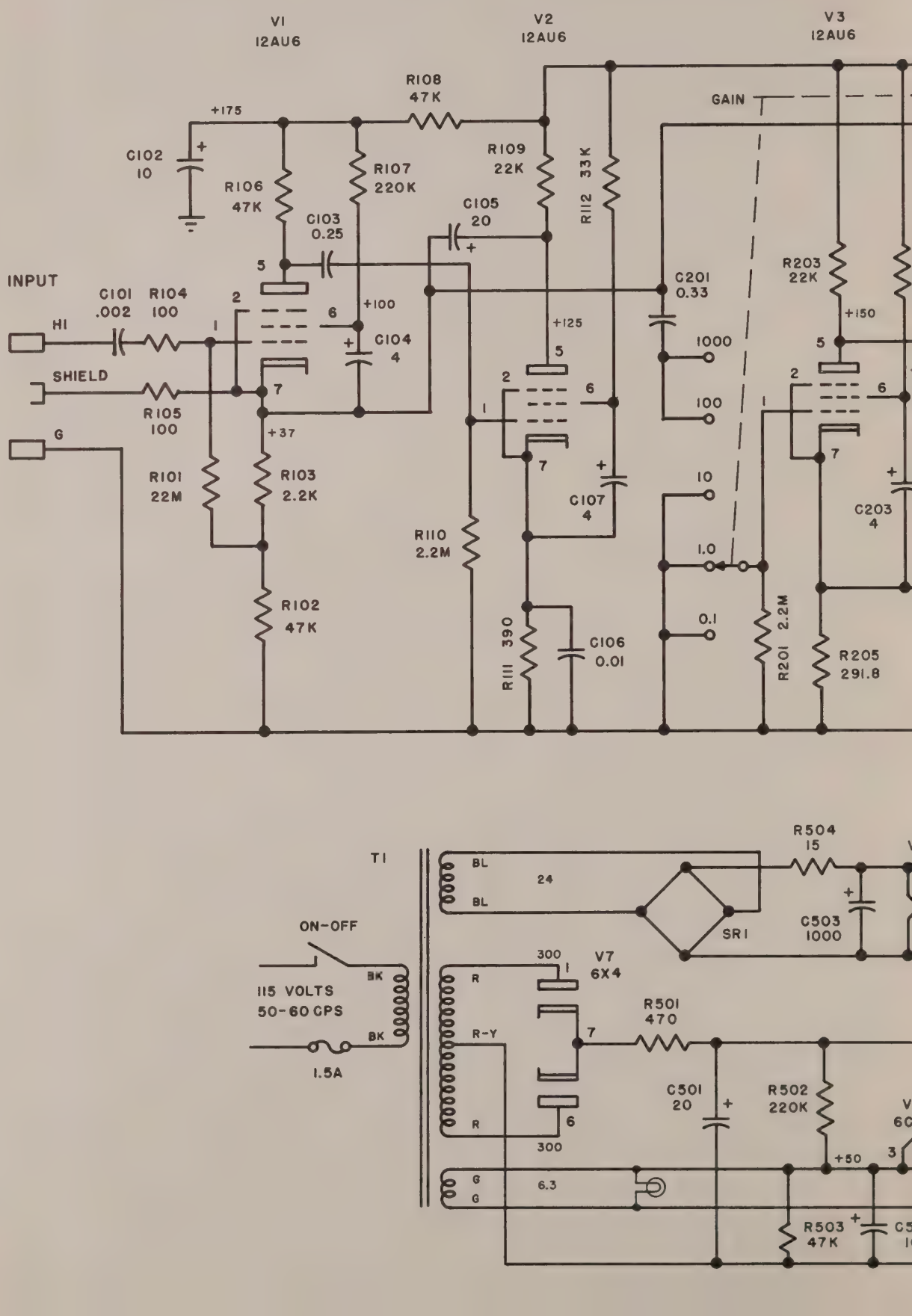
The circuit schematic diagram gives typical dc operating potentials at various parts of the circuit; any large deviation indicates abnormal performance.

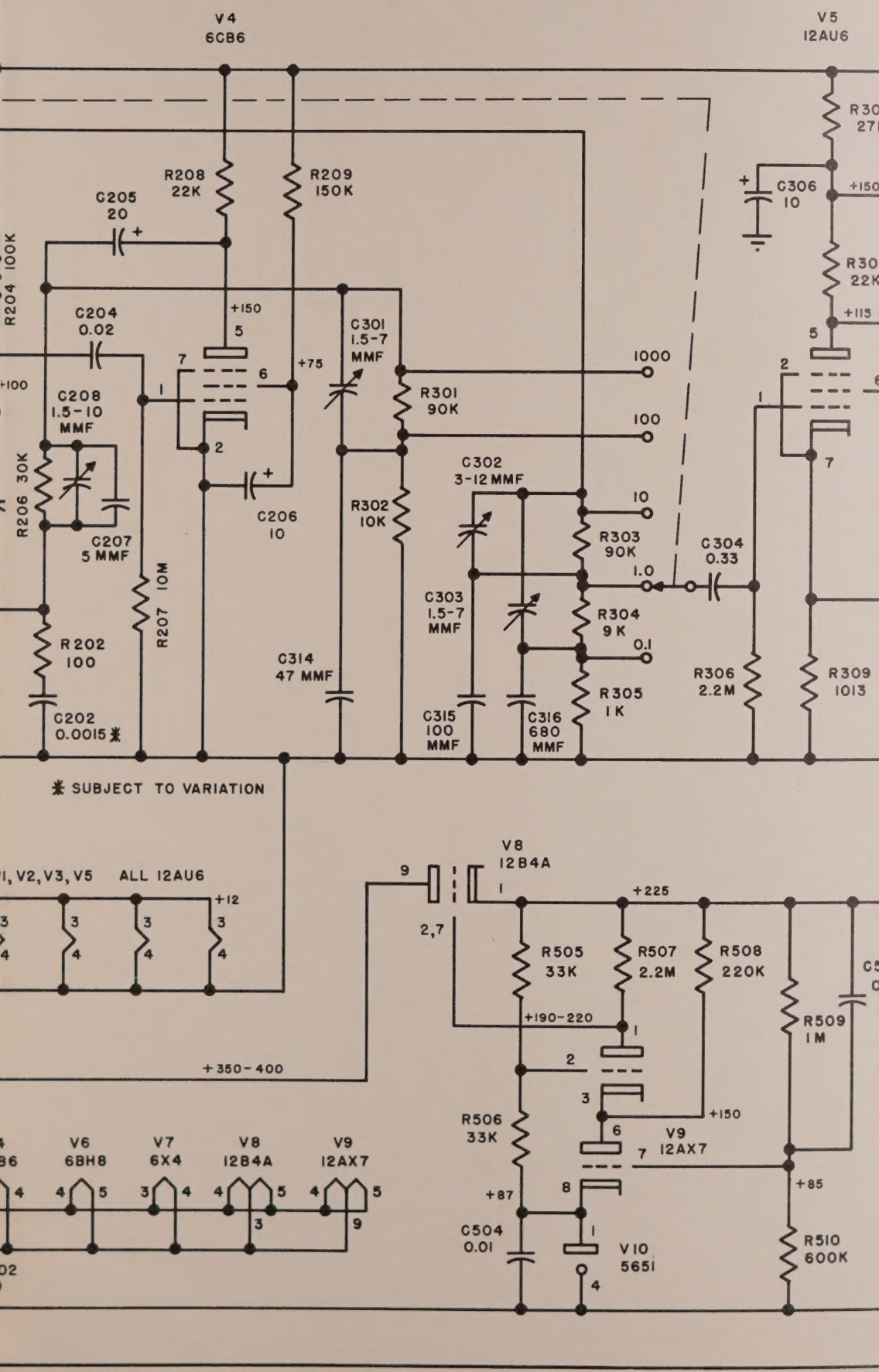
If it should be necessary to remove the panel from the circuit board, the leads to the input terminals and the output terminals should be unsoldered at the terminal. Next, unscrew the nut holding the range switch to the panel. Then remove the screw located near the base, holding the shielding and the chassis to the panel spacer ($\frac{1}{4}$ inch diameter rod); and finally, remove the four screws on the top of the panel, near the handle, which hold the power transformer to the panel. The two sections will then come apart easily. Enough wire has been left on the pilot light and ON-OFF switch, so that they do not have to be disconnected for most work.

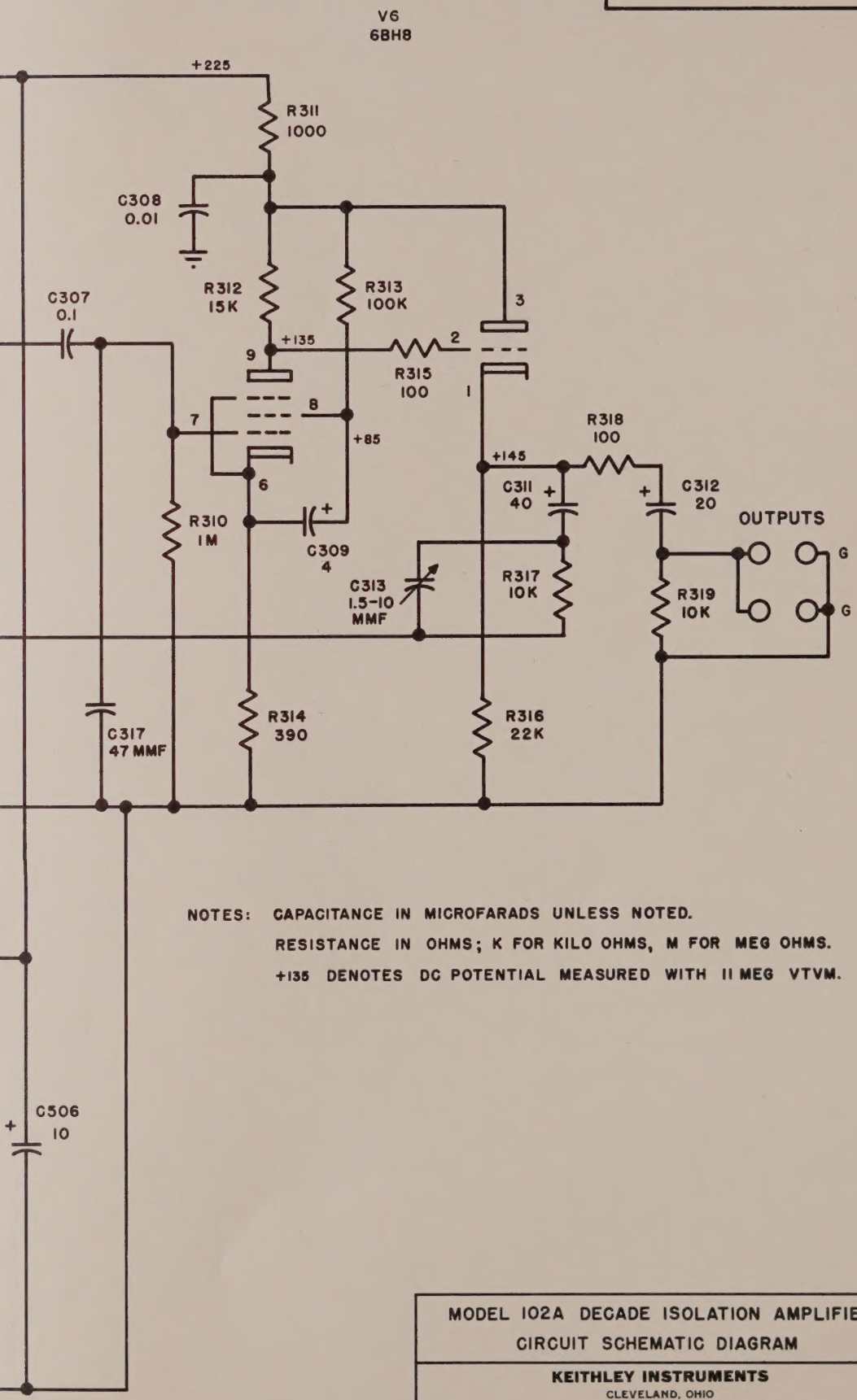
The fuse is located on the central aluminum shield plate next to the transformer. If it fails, the instrument should be checked to determine the cause of the overload, and the circuit corrected before inserting another fuse. It is dangerous to use a fuse rated at more than 1.0 ampere, or to wire the fuse clips together.

The tubes used are not especially selected, and any tube of the proper type should work satisfactorily, except, perhaps, for the 5651 which is discussed in the following paragraph. It would be well to use a tube in the V1 and V3 positions which is not especially microphonic, if much low-level work is to be done.

The regulated B/, as measured at the cathode of V6(12 B4A), should be between 220 to 230 volts, to assure proper regulation with variations in line voltage and enough plate voltage for rated output. This should be kept in mind when replacing V8(5651), for some extreme tube potentials cause the regulated B/ to be outside the 220-230 volt limits. If difficulty is encountered, it can be corrected by using another 5651 or by shunting R512 or R513.


V1
12AU6
V2
12AU6
V3
12AU6
R108
47K
+175
C102
10
R106
47K
R107
220K
C103
0.25
C105
20
R109
22K
R112 33K
GAIN
INPUT
C101
.002
R104
100
HI
SHIELD
R105
100
G
+100
C104
4
+125
C201
0.33
1000
100
10
1.0
0.1
R203
22K
+150
C203
4
R101
22M
R103
2.2K
+37
R102
47K
R110
2.2M
C107
4
R111 390
C106
0.01
R201 2.2M
R205
291.8
T1
ON-OFF
115 VOLTS
50-60 CPS
BK
BK
1.5A
BL
24
BL
SR1
R504
15
C503
1000
300
V7
6X4
R
R-Y
R
300
R501
470
C501
20
R502
220K
+50
G
G
6.3
R503
47K


V4
6CB6
V5
12AU6
R208
22K
R209
150K
C205
20
C204
0.02
C208
1.5-10
MMF
R206 30K
C207
5 MMF
R207 10M
R202
100
C202
0.0015 ✱
C206
10
+150
+75
C301
1.5-7
MMF
R301
90K
R302
10K
C314
47 MMF
1000
100
C302
3-12 MMF
C303
1.5-7
MMF
C315
100
MMF
C316
680
MMF
10
R303
90K
1.0
R304
9K
0.1
R305
1K
C304
0.33
R306
2.2M
R309
1013
C306
10
+150
+113
✱ SUBJECT TO VARIATION
V1, V2, V3, V5 ALL 12AU6
+12
+350-400
V8
12B4A
+225
R505
33K
R507
2.2M
R508
220K
R509
1M
+190-220
R506
33K
+150
V9
12AX7
+87
+85
C504
0.01
V10
5651
R510
600K
V6
6BH8
V7
6X4
V8
12B4A
V9
12AX7



NOTES: CAPACITANCE IN MICROFARADS UNLESS NOTED.
RESISTANCE IN OHMS; K FOR KILO OHMS, M FOR MEG OHMS.
+135 DENOTES DC POTENTIAL MEASURED WITH 11 MEG VTVM.

MODEL 102A DECADE ISOLATION AMPLIFIER
CIRCUIT SCHEMATIC DIAGRAM

KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

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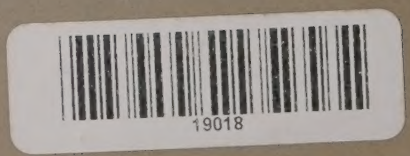
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